Outstanding Pacific Lamprey and White Sturgeon Questions for Portland Harbor RI/FS and NRDA

with suggested investigation concepts

Purpose

Recognizing our interrelated responsibilities under CERCLA, the response agencies, the natural resource trustees, and the Lower Willamette Group (LWG) have endeavored to identify and resolve remaining information shortfalls and knowledge gaps that are impeding comprehensive response and restoration decision making at the Portland Harbor National Priorities List Site (hereafter referred to as the Site). The value of coordination of investigations such that our respective CERCLA response and restoration responsibilities can be simultaneously satisfied was exemplified by the chinook spring-run young of the year effort completed last spring, generally agreed upon as a "success." The third, and possibly final, round of data collection will soon be underway for the Site.

The ultimate goal of this data gathering effort should be to complete assembly of an adequate information set which will be necessary to support risk management decisions and to complement the trustees' injury and restoration scaling decisions. This approach will also allow universal settlement of hazardous substance release liabilities. The optimal approach to finally resolving these issues may be to work with U.S. Environmental Protection Agency (EPA), Oregon Department of Environmental Quality (ODEQ) and the interested members of the LWG to develop and implement such a framework on an expedited timeline.

The trustees earnestly believe that an efficient, adaptable framework that addresses the most important aspects of the information shortfalls must be developed, and we are currently committed to doing so. Ideally, a tiered "if, then, else …" structure could be agreed upon that would logically select which components of the co-designed framework to implement. Resolution of questions by means other than *de novo* data gathering could also be considered to resolve some issues.

Background

Lamprey and sturgeon are important species that can provide valuable guidance in managing the Lower Willamette River. Lamprey are culturally important to Native American tribes, are ecologically important within the food web, and are an indicator species whose decline provides further insight into the impact of human actions on ecological integrity and function. Lamprey populations are declining world-wide, and have been given protected status within Oregon due to declines along the coast and in the Columbia River Basin (Kostow 2002). Similarly, many populations of sturgeon in the Columbia Basin are declining and are of concern. In the course of their migration to the ocean, lamprey ammocoetes are strongly associated with river sediments and, therefore, may provide one of the most sensitive ecological indicators of sediment contamination in the lower Willamette River (Suter 1993); however, no tissue data currently exist to directly assess risk to ammocoetes. Risk analysis of the impacts of sediment contaminants on ammocoetes is likely to improve the quality and appropriateness of risk assessment and the selection of remedial actions in the lower Willamette River.

Some information on the concentrations of contaminants of potential environmental concern (COPEC) in adult lamprey and subadult and adult sturgeon have been collected in the last decade that may indicate potentially harmful exposure to some COPECs by lamprey andsturgeon in the lower Columbia River and/or in the Site, but interpretation of risk to lamprey and sturgeon posed by that exposure is highly uncertain.

Of all groups of fish, lamprey and sturgeon are among the most poorly understood in terms of physiology response and sensitivity to contaminants. Sturgeons (Acipenseriformes) are the last extant representatives of a group of fishes that diverged from other Osteichthyes, via a probable common piscine ancestor shared during the Pennsylvanian to Cretaceous timeframe. Lamprey, Class Cephalaspidomorphi, superclass Agnatha originated in the middle Ordovician and represent an extremely primitive, though highly successful fish. The sturgeon's degree of phylogenetic divergence from the osteichthian fishes typically used to establish toxicological reference values (TRV) has made agreement on selection of surrogate / protective species for risk or injury assessment problematic. The degree of phylogenetic divergence of the agnathan lamprey is even greater than that for sturgeon.

Concerns about relative sensitivity over so large a range of phylogenetic distance means much of the available TRV information for fish has a higher degree of uncertainty than is generally recommended in risk assessment guidance and so relevance of existing TRVs for lamprey and sturgeon remain an unresolved issue. There are several interrelated issues including details of exposure and physiological sensitivity that remain unresolved regarding these highly valuable and exceptionally unique ecological receptors/resources.

In trying to focus and refine remaining information needs and inform a timely technical conversation among all the major parties with interests in the Site, the trustees have compiled in this document a generally comprehensive summation of remaining issues associated with these species, including specific questions and associated studies that are suggested as a framework for meeting our immediate data needs. Remaining information needs may be addressable in a similar fashion later. When possible, the approach is tiered: the results from earlier stages are intended to determine the need for and inform the design of later stages.

This compilation of studies is a conceptual overview of the lamprey and sturgeon studies that the trustee representatives have determined could provide useful information for hazardous substance risk management and/or for the process of determining injuries, scaling injuries, and restoration decision making. Specifically, EPA guidance indicates that risk to receptors from exposure to contaminants should be characterized by assessing two specific parameters: (1) exposure which is operationally defined as the temporal duration of exposure times the concentration of the contaminant to which a receptor is exposed, and (2) the sensitivity of the receptor to the contaminant of concern. The first parameter is typically assessed in the field by (a) empirically measuring or otherwise estimating duration of exposure (e.g., through capture, marking and telemetry / recapture studies) of receptors to contaminants, and (b) measuring contaminant concentrations in the relevant exposure pathway (e.g., water, soil, sediment, air, dietary). The second parameter is typically assessed through laboratory studies of exposure to contaminants of concern. Thus, the studies presented below are a combination of such field and laboratory studies designed to provide information in a timely and cost-effective manner that will replace the most critical assumptions that are likely to have large effects on remedial design with site-specific data.

White Sturgeon (Acipenser transmontanus)

Sturgeons, a bottom-dwelling fish that feeds largely on detritus, clams and other bottom-dwelling biota, have direct contact with bedded sediment and are very long-lived (up to 100 years). Several contaminants tissue concentrations can continue to increase throughout the life of long-lived fish species and may accumulate to levels of potential concern. The interrelated issues of exposure and physiological sensitivity remain unresolved regarding this species.

General Question: Are juvenile, subadult and/or adult sturgeon exposed to sufficient levels of COPECs for sufficient duration to significantly reduce their growth, survivorship and/or reproduction?

Specific Questions:

1. Do contaminant concentrations in juvenile, subadult and/or adult adult sturgeon tissue and/or their prey (based on stomach contents) exceed existing dietary (concentration or dose) or tissue reference values [TRVs]) for other fish?

2. Do adult sturgeon captured in the Site carry a greater body burden of COPECs than younger sturgeon?

Suggested study: Capture and collect a sample (n=25) of prebreeding sturgeons (individuals distributed as evenly as possible between 80-90 cm and 152 cm); capture a sample (n=20) of adult sturgeon (>152 cm to as large as possible) and remove two tissues plugs (4-6 grams each) from each sturgeon.

Analysis: Analyze individual whole-body tissue samples and stomach content samples from prebreeding sturgeon for a limited suite of COPECs. Analyze tissue plug samples from adult sturgeon for a more limited suite of analytes based on (1) results of analyses of prebreeding tissues, and (2) existing data regarding contaminant levels in sturgeon in the Columbia Basin (US EPA 2002, ODHS 2003 unpublished data). Also, conduct health examinations on individual sturgeon following the U.S. Geological Survey, Biological Evaluation of Status and Trends (BEST)-derived methods. These data will allow us to correlate presence/absence, abundance and kinds of morphological abnormalities with concentrations of analytes in tissues and stomach contents.

Specific Question: What is the area of use, site fidelity and duration of exposure of reproductively mature and immature sturgeon?

Suggested Study: Capture juvenile, subadult and adult sturgeon in the Site and attach acoustic tags to them; these tags have a lifetime of 7-15 years. Track these fish for 3 years to document (1) residence time in the Site in relation to fish size (as a proxy for age), (2) site/habitat use within the Site.

Suggestion: Combine this tagging study with on-going studies in the lower Columbia and lower Willamette rivers being conducted by USGS to help share costs and take advantage of existing radio- and acoustic tag monitoring stations, field crews, monitoring efforts, and personnel with sturgeon expertise.

Specific Question: Do concentrations of specific COPECs in water and/or sediment that are less than Ambient Water Quality Criteria (AWQCs) and/or Sediment Quality Criteria (SQCs) being applied to Portland Harbor have deleterious effects on behavior, physiology, growth and/or survivorship of juvenile sturgeon?

Suggested Study: Conduct laboratory toxicity studies with young sturgeon on a refined group of COPECs

a. that have distinct and measurable endpoints related to sturgeon growth and survivorship in toxicity tests, and

b. that have been used successfully in toxicity testing of other fish.

Suggestion 1: Identify contaminants that sturgeon may be exposed to and identify a lab capable of conducting appropriate toxicity tests.

Suggestion 2: Compare bioaccumulative contaminant tissue concentrations to literature-based TRVs.

Specific Question: Does maternal transfer of contaminants adversely affect developing embryos and juveniles?

Suggested Study: Capture gravid females at reference locations. Obtain eggs from these females, analyze them for concentrations of COPECs, and compare the results to existing TRVs developed for other fish species.

Note 1: This study is only warranted if residency time data from study above indicates that juveniles, subadults and/or adults spend sufficient time in the Site to suffer significant exposure to COPECs.

Note 2: If the results to this study indicate that egg tissue values exceed egg TRVs for one or more COPECs, then additional lab studies of the effects of these analytes on the growth and survivorship of eggs are warranted.

Pacific Lamprey (Lampreta (Entosphenus) tridentatus)

Pacific lamprey is an anadromous fish with a complex life history. Juvenile lamprey in the ammocoete stage are filter feeders and can spend up to seven years burrowing in sediment and drifting down tributary reaches, eventually metamorphosing into the macropthalmia stage in preparation for entry into salt water and a parasitic marine life. Juvenile lamprey undergoing metamorphosis are likely to be sensitive to contaminant exposure due to hormonal, physiological and morphological changes necessary for transitioning from life in freshwater to that in saltwater. Other organisms such as amphibians and salmonids have been shown to be very sensitive to contaminants during these transition periods. In addition, juvenile lamprey accumulate lipid just prior to the metamorphosis, relying on these stored lipids to sustain their energy requirements during metamorphosis because they are unable to feed during this time. Juvenile lampreys have been captured in the Lower Willamette River (LWR) in the ammocoete stage and at various stages of metamorphosis. Therefore, juvenile lamprey could be accumulating lipophilic contaminants while feeding in the harbor area and become exposed to these contaminants as lipid stores are used up during a sensitive transition period to another life stage (within the harbor or downstream of the harbor). The ammocoetes could also be exposed to dissolved contaminants during this period within the harbor, either during the filter-feeding stage or during a non-feeding transition period.

After spending time in the ocean as a parasite feeding on fish and marine mammals, adult lamprey return to freshwater to spawn. Some adult lamprey return to the spawning areas after passing through the lower Columbia and lower Willamette Rivers. Recent data (USGS, unpublished data) indicate that some adult lamprey may not pass through the LWR rapidly but, instead, spend up to two years in freshwater prior to reaching their spawning areas. Adult lamprey can be exposed to dissolved contaminants through the skin and gills during their upriver migration, especially while in the LWR. Adult lamprey do not feed while in freshwater, but rely on their large lipid stores for energy. During lipid metabolism, increased exposure of target organs may occur, and maternal transfer of contaminants in adult females could threaten survival and growth of eggs and ammocoetes.

General Question: Are lamprey ammocoetes, macropthalmia, and/or adults exposed to sufficient levels of COPECs for sufficient duration to significantly reduce their growth, survivorship and/or reproduction?

Specific Question: What are the habitat preferences of young lamprey in relation to body size and stage of development (ammocoetes vs. macropthalmia)?

Habitat preferences of young Pacific lamprey are poorly understood; however, there is some evidence that ammocoetes prefer relatively fine-grained, silty habitat whereas macropthalmia prefer coarser, cobbly habitat. Because the concentration and bioavailability of contaminants may vary in relation to such aspects of the physical structure of the substrate, risk to lamprey should be evaluated by collecting ammocoetes and macropthalmia across these habitat types.

Suggested Study: Identify and categorize substrate types in the Site using (1) sediment profile imaging data, and (2) sediment grain size. Collect samples of ammocoetes among these habitats using a stratified sampling approach to determine whether ammocoete presence, absence or density varies at the Site in relation to depth and substrate type.

Sampling ammocoetes in deepwater habitats like the LWR presents challenges because of the difficulties of capturing infaunal organisms with highly patchy distributions in deep water. Successful sampling in the Great Lakes has used a modified electrofisher with suction (Bergstedt and Genovese 1994) that would also be suitable for the LWR.

Due to the difficulties of sampling ammocoetes in deepwater habitat, we must conduct a pilot study during which we will evaluate and, if necessary, refine this methodology developed by Bergstedt and Genovese (1994). In shallow areas, a quadrat will be sampled with the deepwater shocker, and then sampled with a suction dredge (the deepwater shocker with the shocking unit replaced with a rigid tube) to identify the number of individuals missed by the shocking unit. In deeper water co-locating samples and using the suction dredge would require divers, so instead at each sampling location a deepwater shocker and ponar dredge will be used to provide a general qualitative comparison of the two methods.

In addition to stratified sampling, adaptive sampling will be conducted at locations where higher densities of ammocoetes are encountered to hopefully increase our capture efficiency. Any location where four or more ammocoetes are captured, or two adjacent locations where a total of four ammocoetes are captured, will be allocated additional sample locations 25 m upstream and downstream of the original sample. If these adaptive samples also show higher densities then additional samples will be allocated 25 m upstream or downstream until we obtain the mass of ammocoetes desired for the location or low densities are encountered.

Specific Question: Do juvenile lamprey accumulate potentially toxic concentrations of COPECs in the Site?

Suggested Study: Collect ammocoetes and macropthalmia of various sizes using various potential collection methods (e.g. specialized electroshock-dredging techniques discussed above), analyze the composite whole body tissue samples for concentrations of COPECs, and compare these data to TRVs.

Note: Samples of ammocoetes and macropthalmia for this study will be collected while conducting the study above.

Suggestion: Efficiency of collection of ammocoetes and macropthalmia may be achieved by attempting to identify suitable habitat for these life stages based on sediment profile index data and sediment grain size data.

Specific Question: What is the direct toxicity of site-related COPECs to juvenile lamprey?

Suggested Studies: Obtain ammocoetes (either cultured in the lab at NOAA NWFSC or captured at "clean" sites in the Pacific Northwest) and conduct toxicity studies (water-only, sediment, and/or dietary exposure) with a refined group of COPECs

a. that have distinct endpoints related to lamprey growth, survivorship and/or mortality and measurable in toxicity tests, and
b. that have been used successfully in toxicity testing of other fish.

Analysis: In addition to measuring endpoints related to lamprey growth, survivorship and/or mortality (to be identified above), measure and compare bioaccumulative contaminant tissue concentrations to literature-based TRVs.

Specific Question: Do adult lamprey accumulate potentially toxic concentrations of COPECs in the Site?

Suggested Study: Collect a sample of adult lamprey immediately upstream (n=20) and immediately downstream (n=20) of the Site upper and lower boundaries, respectively.

Analysis: If adults accumulate significant concentrations of COPECs while in the Site, then the mean concentration of one or more analytes in the upstream sample will be significantly greater than that of the same analyte(s) in the downstream sample.

Specific Question: While fasting in freshwater, does their risk of exposure to toxic levels of COPECs increase as they metabolize lipid to maintain themselves and support their reproductive activities?

Suggested Study: Determine the relationship between percent lipid composition and analyte levels in individual lamprey that vary substantially in percent lipid composition. To achieve this, it is likely best to capture a sample of adults soon after entering freshwater (preferably as close to the mouth of the Columbia River as possible, but potentially further upstream if necessary) and another sample later in the summer (e.g. toward the end of harvest season in late July).

Specific Question: Does accumulation of COPECs by adult females while in the Site pose a significant risk to their offspring, i.e. to the growth and survival of their eggs and ammocoetes?

Suggested Study: Capture and collect gravid adult females at Willamette Falls, and analyze egg samples from individual and/or multiple females (i.e. composite samples of eggs). Compare results to egg TRVs for other fish species, assuming that egg TRVs developed for other fish are protective of lamprey.

Specific Question: Are existing egg TRVs protective for lamprey?

Suggested Studies: Obtain eggs from gravid adult females at relatively "clean" sites in the Pacific Northwest and conduct toxicity studies (water-only, sediment, and/or dietary exposure) on them with a refined group of COPECs

a. that have distinct endpoints related to lamprey growth, survivorship and/or mortality and measurable in toxicity tests, and

b. that have been used successfully in toxicity testing of other fish.

Note: This study may be combined with the lab study discussed above regarding toxicity of COPECs in ammocoetes and macropthalmia.

Specific Question: What is the duration of exposure of adult lamprey to COPECs in the Site?

Suggested Study: If possible, capture adult lamprey downstream of the Site (trapping techniques for doing so are currently being developed and tested by USGS), tag them with acoustic transmitters, determine their residency time while migrating through the Site, and track their movements until they spawn. Alternatively, if adults can not be captured downstream of or within the Site, capture them at Willamette Falls and track their movements. Recent research by USGS (Mesa unpublished data) indicates that many individuals that reach Willamette Falls subsequently move downstream through the Site for unknown reasons. This research can be cost-shared with USGS, and is a great opportunity for the LWG and/or the NRG

Specific Question: Do adult lamprey avoid concentrations of COPECs in water below existing screening levels (AWQCs)?

Some fish can detect and avoid some, but not other contaminants. Further, some contaminants interfere temporarily or permanently with olfactory function, including their ability to locate their natal spawning grounds by olfactory cues, thereby reducing or eliminating their ability to reproduce

Suggested Study: Capture adult lamprey in the field and test their responses to COPECs in the lab that have been demonstrated to elicit avoidance behavior in other fish species (e.g., salmon).

Specific Question: Do COPECs cause temporary or permanent impairment of olfactory function in adult lamprey at water concentrations below existing screening levels (AWQCs)?

Suggested Study: Capture adult lamprey from relatively “clean” locations in the field and test their responses to COPECs in the lab that have been demonstrated to elicit avoidance behavior in other fish species.

Literature Cited

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